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SYNTHETIC BOTTLE STOPPER

Field of the Invention

The present invention relates to a synthetic bottle stopper. More in particular, the present invention relates to a bottle stopper made from a foamed
5 thermoplastic elastomer comprising one or more thermoplastic block copolymers and a blowing agent.

Background of the invention

Cork is a natural occurring material regularly used for the production of stoppers for casks, vials and
10 bottles (also referred to as "bung" or "moulded closure for a liquid container", etc.). Cork has a good grip on glass, and requires an appropriate force of about 250-430 N to pull off the cork from a bottle. Stoppers made of cork can be used for closing a half-used bottle
15 for a second time. Besides, swell of cork stoppers when in contact with wine improves their grip. Also, cork is a light material (density of about 0.22 kg/m^3), which is important to control the cost when transporting the cork and/or the bottles wherein the cork stoppers are used.
20 Cork is hence a popular material in the production of stoppers.

However, stoppers made of cork may become infected by fungi and bacteria, and they may impart undesired flavour and colour to the contents of the vials and bottles
25 wherein they are used. Moreover, good quality cork is becoming rare and hence expensive. Accordingly, synthetic bottle stoppers have been developed.

Obviously, these synthetic bottle stoppers need to perform similar to cork as regards the elasticity of the
30 material, long term creep, good control during insertion and manufacture, and possibility of reinsertion. Most

importantly, they need to be light, i.e., have a density of less than about 0.7 kg/m^3 , preferably of about 0.5 kg/m^3 .

Synthetic stoppers for vials and bottles are known.

5 International application 99/01354 (Supreme Corq) discloses a synthetic cork for removable insertion into an opening of a bottle comprising a hard plastic top and a shaft made of a thermoplastic elastomer (TPE) combined with a blowing agent, wherein the TPE consists of one or
10 more styrenic block copolymers. Suitable styrenic block copolymers are selected from the group corresponding to the general formulae A-B or A-B-A, wherein "A" represents a polystyrene block and "B" represents a polybutadiene block, a polyisoprene block, a hydrogenated polybutadiene
15 block or a hydrogenated polyisoprene block. Suitable blowing agents comprise azodicarbonamide or a masterbatch thereof sold under the tradename "SPECTRATECH FM1150H", ozodecarbonoxide and sodium bicarbonate. The mixture used for forming the shaft may also incorporate a minor amount
20 of low density polypropylene.

International application 94/25513 is an earlier application by Supreme Corq, disclosing a synthetic cork (referred to as "molded closure for a liquid container") comprising the TPE and blowing agent mentioned above.

25 US patent No. 3,984,022 (assigned to Le Bouchage Mécanique) discloses a bottle stopper of biconical configuration, which is made from a foamed plastic with a dense outer layer enclosing a closed cellular or honeycomb structure around the centre. The stopper is
30 produced by injection of a plastic material, which may be a polyolefin such as polyethylene or EVA (ethylene-vinyl acetate), with a pore-forming additive into a mould.

US patent No. 4,499,141 (assigned to the Coca Cola Company) discloses a plastic closure for sealing liquid
35 product containers wherein a synthetic cork article is

prepared from a thermoplastic resin and a blowing agent, e.g., azodicarbonamide, and whereby the plastic article is injection moulded.

5 US patent No. 4,188,457 (assigned to Metal Box Limited.) discloses a "bung" for closing a wine bottle in the manner of a cork, which is formed in a conventional injection-moulding machine from ethylene-vinyl acetate copolymer (EVA) with the addition of sodium meta-

10 bisulphite and sodium bicarbonate. These synthetic bottle stoppers, however, are either too dense and/or too hard. As a result, these bottle stoppers will be difficult to insert (problem of leakage), and to remove (in one piece) with an ordinary corkscrew. Moreover, it may be difficult to insert a
15 corkscrew if the stopper is too hard. Besides, these synthetic stoppers (or at least those of Supreme Corq) require the presence of a plasticiser in the form of an oil. If no or too little oil is used, then the thermoplastic elastomer composition will be too viscous and the
20 cells therein will not be able to expand. The end-result is a dense "foam". If too much oil is used, then the viscosity will be too low and cells collapse, with the same end-result. Such bottle stoppers therefore require a precise operating window (about 30-40 parts per hundred
25 parts of elastomer). Unfortunately, oil is a potential contaminant of the contents of the bottle. There is therefore a demand for a new foamed thermoplastic elastomer composition that provides synthetic bottle stoppers of suitable density, and that requires no or
30 only a little oil as plasticiser.

Summary of the invention

The present invention provides a synthetic bottle stopper made from a foamed thermoplastic elastomer composition comprising

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- a) one or more thermoplastic block copolymers
c) a blowing agent, and optionally
d) one or more plasticisers,
characterised in that the composition further comprises
5 b) one or more branched polyolefins having a melt flow
index ('MFI') of from 0.05 to 400 (at 2.16 kg/190 °C,
determined in accordance with ASTM D 1238).

Detailed description of the invention

10 The synthesis of foamed TPE compositions is known. In
addition to the references cited herein before, such
compositions are described in Japanese patent application
No. 58173146 (Yokohama Rubber KK, Derwent abstract
No. 83-822911/47). This reference describes a composition
15 comprising a thermoplastic block copolymer and a
thermoplastic resin and/or plasticizer or softener. The
composition forms a non-adhesive foaming material and can
be used as a packing or gasket material.

20 In US patent No. 4,764,535 (assigned to Q'SO Inc.) a
composition is described comprising a mixture of two
thermoplastic elastomers, a nucleating agent and an
unstable resin. The compositions may be employed in
formulating coatings, laminates, hot melt adhesives and
caulking compounds.

25 Hot melt compositions from which foamed products can
be obtained are disclosed in US patent No. 4,529,740
(assigned to W.R. Grace & Co.). The compositions include a
thermoplastic elastomer, a small amount of a salt of a
sulfonated styrene polymer, and a blowing agent. The
composition may be used to produce foamed products suited
30 for example as sealants in closures for containers.

35 Plastic foam products are also disclosed in US patent
No. 5,585,411 and International application No. 94/28066
(both to Shell). In the former, a plastic foam is
disclosed that is made from a blend comprising poly-1-
butene, a styrenic block or star copolymer, and/or an

olefinic rubber, and optionally a non-elastomeric polyolefin. These foams are particularly useful in very high temperature applications such as pipe wrap in refrigerators. In the latter a novel elastomeric poly-1-butene is described, as well as blends thereof with compatible materials, which are particularly suitable in textile and fibre applications, and blends thereof with incompatible materials, which are particularly useful in easy-open packaging applications, in foam applications and in PVC replacement.

The use of a composition as described in claim 1 for the purpose of preparing a superior synthetic bottle stopper is neither disclosed nor hinted at in any of these references. The components of the composition are described in more detail herein after.

Component a)

The expression "thermoplastic block copolymer" refers to a polymer having two or more distinguishable polymer blocks, of which at least one is glassy or crystalline at service temperature but fluid at higher temperatures, and at least one of which is elastomeric (rubbery) at service temperature. A comprehensive review on such polymers is provided by Messrs. Legge, Holden and Schroeder, in "Thermoplastic Elastomers", published by Hanser Publishers in 1987 (ISBN 3-446-14827-2). Such polymers include thermoplastic polyurethane elastomers and various other block copolymers.

The preferred thermoplastic block copolymers in accordance with the present invention, are styrenic block copolymers, i.e., wherein the or each glassy polymer block of the block copolymer is made of polymerized vinylaromatic monomer, such as styrene, in an amount of at least 80 mole % on the total monomer content of the glassy polymer block. Styrene is the preferred vinylaromatic monomer, but other suitable vinylaromatic

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monomers include α -methylstyrene, p-methylstyrene, m-methylstyrene, o-methylstyrene, p-tert-butylstyrene, dimethylstyrene, and various other alkyl-substituted styrenes, alkoxy-substituted styrenes, vinyl naphthalene and vinyl xylene. The alkyl and alkoxy groups of the alkyl-substituted or alkoxy substituted styrenes respectively preferably contain from 1 to 6 carbon atoms, more preferably from 1 to 4 carbon atoms. Comonomers, if present, may be selected from (di)olefins and other compounds copolymerizable with styrene.

Preferred styrenic block copolymers are those wherein the or each elastomeric polymer block of the block copolymer is made of polymerized conjugated diene, such as butadiene or isoprene, in an amount of at least 80 mole% on the total monomer content of the elastomeric polymer block. Butadiene and isoprene are the preferred dienes, but other suitable conjugated dienes include dienes with from 4 to 8 carbon atoms per monomer, for example, 2-ethyl-1,3-butadiene, 2,3-dimethyl-1,3-butadiene, 1,3-butadiene, 1,3-pentadiene, 2,4-hexadiene, 3-ethyl-1,3-pentadiene, and mixtures thereof. Comonomers, if present, may be selected from vinylaromatic monomers and other compounds copolymerizable with the diene.

The vinyl content of the elastomeric polymer block (i.e. that part of the conjugated diene that is polymerized in a "1,2-fashion") is preferably at least 55% (mol/mol on total conjugated diene), more preferably in the range of 65-80%. These styrenic block copolymers have greater ease of processing, require even less plasticizer, and add increased melt strength and drawability to the thermoplastic elastomer composition.

Still more preferred, are styrenic block copolymers that have at least one elastomeric polymer block made of polymerized conjugated diene that is hydrogenated. In

other words, the hydrogenated version of the block copolymers mentioned above. Suitably, such block copolymers are selectively hydrogenated (i.e., only the elastomeric polymer blocks), to a degree of 80% or more based on the (original) residual unsaturation.

Excellent synthetic bottle stoppers have been made from styrenic block copolymers having an overall content of vinylaromatic monomer in the range of 10 to 50% by weight, preferably 20 to 45% by weight. Most preferred are such styrenic block copolymers having a total apparent molecular weight in the range from 30,000 to 400,000 g/mol, more preferably from 50,000 to 300,000 as measured with gel permeation chromatography (GPC) using polystyrene calibration standards (according to ASTM D 3536).

Block copolymers come in the form of linear diblocks, triblocks and multiblocks (produced with sequential polymerization techniques or difunctional coupling agents), or branched block copolymers (using multifunctional coupling agents and/or re-initiation techniques). The preferred block copolymers in accordance with the present invention are linear triblock copolymers, or blends of triblock copolymers, containing up to 30% weight/weight of diblock copolymers.

Suitable block copolymers include, amongst others, those sold by Shell under the trademark "KRATON", and those sold under the trademarks "DYNAFLEX" (CC&P), "VECTOR" (DECXO), "EUROPRENE" (ENICHEM); "QUINTAC" (NIPPON ZEON); "FINAPRENE" (FINA); "STEREON" (FIRESTONE); "TUFRENE" (ASAHI) and "SEPTON" (KURARAY). Particularly suitable are "KRATON" elastomeric block copolymers sold as grade D1102, KX225, G1650, G1652, G1657, G1701, G1726, G1730, G1750 and G1780.

Component b)

A branched polyolefin is a polymer having alkyl groups containing 2 or more carbon atoms attached to the backbone. Such polyolefins are known as high melt strength polymers and hence impart high melt strength and drawability to blends thereof with (styrenic) block copolymers. Such branched polyolefins include e.g., high melt strength propylene polymers, containing long-chain branches inside the polypropylene, disclosed by Dr. Ulf Panzer at the SPO '98; and poly-1-butylene as disclosed in e.g., US Patent No. 4,960,820 which is herein incorporated by reference. Suitable polyolefins have a melt flow index ('MFI') of from 0.05 to 400, preferably from 0.1 to 200, even more preferably from 0.2 to 20 and most preferably from 0.4 to 5 dg/min at 2.16 kg/190 °C. They may be produced by the polymerisation of an alpha- or internal alkene having 3 or more carbon atoms using the Daploy process disclosed by Dr. Pzanzer, or by (Ziegler-Natta low pressure) polymerization of an alpha- or internal alkene having 4 to 10 carbon atoms, preferably a linear alkene such as 1-butene, 1-pentene, 2-pentene, 1-hexene, 1-heptene, 1-octene, or the copolymerization of these alkenes with e.g., up to 10 mole% ethene and/or propene (e.g., as described in DE-A-1,570,353). Preferably the branched polyolefin contains from 80%, more preferably from 95% and most preferably from 97% by weight of isotactic portions. Branched polyolefins that have been found to be very suitable are polymers of 1-butene, having a 1-butene content of at least 50 mole%, preferably at least 70 mole%. The most preferred branched polyolefin is poly-1-butene.

The weight average molecular weight of the polyolefin may range from 60,000 to 1,000,000 g/mol, determined by GPC, using poly-1-butene standards. Suitable polyolefins

have a density of from 0.875 to 0.925, preferably from 0.900 to 0.920 and most preferably from 0.910 to 0.915.

Poly-1-butene PB-0110, marketed by Shell is a particularly suitable polymer. This polymer is a homopolymer with a melt index of 0.4 g/10min. at 190 °C and 2.16 kg and a weight average molecular weight of 800,000.

Component b) is preferably used in an amount of 10 to 100 parts per 100 parts of component a) ('phr'), more preferably in an amount of 30 to 80 phr.

Component c)

Plasticisers are well known to those skilled in the art. Typically, the hardness of polymer compound is decreased by adding a plasticiser. The plasticiser is typically substantially compatible with at least the elastomeric polymer blocks of the thermoplastic block copolymer used as component a).

Examples of plasticisers commonly used in respect of the preferred elastomeric block copolymers include hydrocarbon oil, preferably naphthenic or paraffinic oil, more preferably paraffinic oil. Examples of alternative plasticisers which may be used in the compound of the invention are, oligomers of randomly or sequentially polymerised styrene and conjugated diene, oligomers of conjugated diene, such as butadiene or isoprene, liquid polybutene-1, and ethylene-propylene-diene rubber, all having a weight average molecular weight in the range from 300 to 35,000, preferably from 300 to 25,000, more preferably from 500 to 10,000.

Whereas the presence of such plasticisers in the prior art formulations is essential, as in mentioned herein before with respect to the Supreme Corq bottle stoppers, the presence thereof in the present formulation is only optional, and in the preferred embodiment even absent. If present, then such plasticisers may be used in

an amount of up to 50 phr, preferably in an amount of up to 30 phr, more preferably in an amount of up to 20 phr.

Blowing agent

5 As noted above the foamed thermoplastic elastomer composition of the present invention also contains a blowing agent. Normally a blowing agent decomposes above a certain temperature thereby releasing gas, such as nitrogen, which causes a volume increase of the reaction mass. The temperature at which the blowing agent starts
10 decomposing is further referred to as the activation temperature. In principle, any known blowing agent such as the ones mentioned above, and more particular as described in US patent No. 5,585,411 may be used. Generally known blowing agents are for instance sodium
15 bicarbonate, azodicarbonamide-based compound and diphenyloxide-4,4'-disulphohydrazide. The latter is commercially available under the tradename "GENITRON" OB, while an azodicarbonamide-based masterbatch is commercially available under the tradenames "GENITRON"
20 PB10 or "CELOGEN" 754A.

Alternative blowing agents are heat expandable thermoplastic particles encapsulating heat expandable gas or liquified gas. Such heat expandable thermoplastic particles are known in the art and available commercially
25 under the tradename "EXPANCEL". Further details regarding such heat-expandable thermoplastic particles can e.g. be obtained from European patent application No. 717,091, which is incorporated herein by reference.

Preferably, the blowing agent is azodicarbonamide or sodium bicarbonate or mixtures thereof. Especially good
30 results may be obtained with sodium bicarbonate.

The blowing agent is preferably present in an amount from 1 to 10 %wt., basis the total composition, more preferably 1 to 5% by weight.

Other components

Optionally, the foamed thermoplastic elastomer composition comprises further components. Such other components include the "olefinic rubbers" mentioned in US
5 patent No. 5,585,411; the compatible and incompatible materials mentioned in WO 94/28066, etc.

For instance, the composition may further comprise from 5 to 50 phr of a polyolefin other than the branched polyolefin, e.g., selected from polyethylene,
10 polypropylene and copolymers thereof. Preferably, the polyolefin is polypropylene or polyethylene, in particular LLDPE. More preferably, the polyolefin is polypropylene.

The foamed thermoplastic elastomer composition may
15 also comprise polymers that are compatible with the glassy polymer blocks of the thermoplastic block copolymers, such as polyphenylene ether and/or polystyrene. For instance, the composition may comprise from 5 to 50 phr of such polymers.

It will be appreciated that the compounds of the present invention may further contain additional compounds like stabilisers, fillers, slipping agents (compounds that are known to provide grip to the glass, such as stearates, eureamide and/or kenamide), waxes and
25 colouring agents (pigments) and even bits of natural cork to give the stopper a cork-like appearance.

The compositions of the invention can be prepared according to procedures well known to those skilled in the art. For instance they may be made by extrusion and
30 melt blending. Examples of apparatus which may be used to prepare the compositions of the present invention include, but are not limited to, single or multiple screw extruders, mixing rollers, internal mixers, Banbury mills, and kneaders. For example, the compositions of the
35 present invention may be prepared by feeding ingredients

either partly or fully as a pre-blend or separately in a discontinuous or continuous mixer. The mixer is preferably a continuous mixer. If in first instance compositions are produced that do not contain a blowing agent then we prefer a twin-screw extruder is used, in particular a co-rotating twin-screw extruder.

The composition ingredients are preferably pre-blended as follows. If a plasticiser is used, then first the block copolymer is blended with part or all of the plasticiser. The latter is preferred. The plasticiser and block copolymer may be blended by contacting the plasticiser and oil and rolling, tumbling or mixing in suitable apparatus. Alternatively, the block copolymer and plasticiser may be melt mixed using apparatus such as single or multiple screw extruders, mixing rollers, internal mixers, Banbury mills, and kneaders. If pre-blending block copolymer and plasticiser is conducted in an extruder, then the plasticiser is typically metered into the extruder such that the metering rate is matched to the proportion of oil and polymer desired in the final composition.

The pre-blending step is typically carried out in a so-called turbo-mixer, such as a "Papenmeier" mixer.

The block copolymer or blend of block copolymer and plasticiser is then blended with the branched polyolefin (e.g., poly-1-butene), and any other ingredients such as filler, polyolefin, polyphenylene ether, syndiotactic polystyrene, stabilisers, waxes and/or pigments. Subsequently, blowing agent may be added, either in the same or a separate blending step. Alternatively, and most preferably, no blowing agent is added at this stage and first a composition without blowing agent is produced.

If a composition without blowing agent is produced, then the composition may subsequently be pre-blended or tumble-mixed with a blowing agent to prepare a

masterbatch as will be discussed in more detail herein after.

5 If a composition with blowing agent is produced, care should be taken that during the compounding process the temperature is kept below the blowing agent decomposition temperature unless (full or partial) foaming is desired during this first step.

10 The preparation of a foamed thermoplastic elastomer composition as described above comprises a second aspect of the present invention. In order to produce the "cork", the composition is injected into a mould, e.g. as described in US patents Nos. 3,984,022 and/or 4,499,141. Alternatively, the present composition allows corks to be made via extrusion, which is much preferred over
15 injection moulding since producing uniform corks in a continuous fashion at a higher rate. A third aspect of the present invention concerns foamed articles (including, but not limited to corks) obtainable by this preparation.

20 The invention is illustrated by the following examples.

Examples

The following ingredients were used in the Examples:

PF814	a high melt strength polypropylene (MFI = 3, 230 °C/2.16 kg) commercially available from Montell polyolefins.
PB0110	a high melt strength poly-1-butene (MFI = 0.4, 190 °C/2.16 kg; MP is about 125 °C) commercially available from Montell polyolefins.
"PRIMOL" 352	Paraffinic oil.
"KRATON" G1652 ('KG1652')	a linear styrene-ethylene/butylene-styrene block copolymer having a polystyrene content of 29% by weight, available from Shell Chemicals companies.
"KRATON" G1701 ('KG1701')	a linear styrene-ethylene/propylene block copolymer having a polystyrene content of 28% by weight, available from Shell Chemicals companies.
"IRGANOX" 1010	tetrakis-ethylene-(3,5-di-tertiary-butyl-4-hydroxy-hydrocinnamate)methane.
"IRGANOX" PS800	dilauryl thiopropionate.
"GENITRON" PB10	a masterbatch of 10% weight azodicarbonamide in a LDPE carrier, available from Bayer.
"CELOGEN" 754-A	activated azodicarbonamide in powder form, available from Uniroyal Chemicals.

TPE Compositions

5 Compositions not containing blowing agent were prepared as follows. 100 parts by weight of a KG1652 were blended with a desired amount (0 or 30 parts by weight,

phr) of "PRIMOL" 352 in a Papenmeier mixer for 10 minutes at room temperature.

To the pre-blend thus obtained were added the desired amount (0 or 25 phr) of KG1701, a desired amount (27 or 54 phr) of poly-1-butene and a desired amount (0 to 54 phr) of polypropylene and stabilisers. Blending was continued for 5 minutes.

The pre-blend thus obtained was fed into a co-rotating twin-screw extruder (Werner-Pfeifferer) to produce various compositions. The temperature in the twin-screw extruder ranged from 140 to 200 °C. The twin-screw extruder is equipped with a strand die. The strands obtained are cooled down in a water bath and cut into pellets with a pelletiser. Table 1 depicts the breakdown of compositions A-D, all in parts by weight.

Table 1

Compound	A	B	C	D
KG1652	100	100	100	100
KG1701		25	25	25
"PRIMOL" 352				30
PB0110	54	54	54	27
PF814		54	27	27
"IRGANOX" 1010	0.2	0.2	0.2	0.2
"IRGANOX" PS800	0.2	0.2	0.2	0.2

Pellets of compositions A and B obtained above were dry-blended with 3% by weight of azodicarbonamide as blowing agent to prepare masterbatches A and B. The blowing agent used in example 1 was "GENITRON" PB10.

The masterbatches A and B thus obtained were fed into a single screw lab extruder (Extrudex), using a temperature profile of 190 °C at the feed entrance, 200 °C at the end of the extruder and 210 °C at the die, to prepare foamed compositions A and B. The die was a

strand die of 6 mm. The density of the foamed strands obtained and the compounds prior foaming were measured. Results are shown in Table 2.

Table 2

Compound	Density
A prior foaming	0.90
A + 3% blowing agent	0.66
B prior foaming	0.91
B + 3% blowing agent	0.54

Both compositions A and B show a good density decrease with 3% of blowing agent. The best density decrease is obtained with composition B containing a mixture of triblock and diblock copolymers.

Example 2

Pellets of compositions A and B obtained in example 1 were dry-blend with 2.5 or 3% by weight of "GENITRON" PB10 as a blowing agent to prepare masterbatches.

The masterbatches thus obtained were fed into an injection moulding machine (Battenfeld), using a temperature profile of 190 °C at the feed entrance 200 °C at the end of the extruder and 210 °C at the die, to prepare foamed specimen A and B. The foamed specimen obtained by the injection were circular plates with a diameter of 45 mm and a thickness of 6 mm. The density of the foamed specimen were measured and the results are shown in Table 3.

Table 3

Composition	Density
A + 2.5% blowing agent	0.53
B + 2.5% blowing agent	0.52
B + 3% blowing agent	0.52

Both compounds show good density decrease with 2.5% by weight of blowing agent and an increase of blowing agent did not result in a decrease of the density.

Example 3

5 Pellets of compositions A, C and D were dry-blended with 5% by weight of azodicarbonamide as blowing agent to prepare masterbatches A, C and D. The masterbatch A and C has been prepared with the blowing agent "GENITRON" PB10. The masterbatch D has been prepared with the blowing
10 agent "CELOGEN" 754-A.

The masterbatches A, C and D thus obtained were fed into an injection moulding machine (Negri Bossi & C), using a temperature profile of 170 °C at the feeding entrance, 190 °C at the end of the extruder and 190 °C at
15 the die to prepare foamed specimens A and C. The temperature profile was 160 °C at the feeding entrance and 180 °C at the end of the extruder and at the die to prepare specimens D. The foamed specimens obtained were stoppers of 38 mm by length and a diameter of 22 mm. The
20 density of the stoppers were measured and the results are shown in Table 4.

Table 4

Composition	Density
A + 5% blowing agent	0.63
C + 5% blowing agent	0.56
D + 5% blowing agent	0.54

The best density decreases were obtained with compositions C and D, containing linear styrene-ethylene/propylene block copolymer.

25 The foaming conditions have not been optimised in examples 2 and 3. For instance, optimisation of foaming conditions such as optimum temperature profile and die

pressure is expected to lead to further density reduction to e.g. 0.5.

It is known that poly-1-butene crystallises only slowly. If desired, nucleating agents may be used to increase the crystallisation rate. Nucleating agents are well known to those skilled in the art and available commercially. The most popular nucleating agent is Talc, but the use of stearamide is also well known.

Example 4

Foamed stoppers C and D thus obtained in example 3 have been inserted in glass bottles filled with water, using a manual cork insertion machine. An ordinary corkscrew was then fixed into the stoppers. The bottles have been then fixed in a tensile machine (Zwick) while the corkscrew was fixed at the moving crosshead. The stoppers were pulled out of the bottle at a constant speed of 100 mm/min. The force needed to extract the stoppers was measured and the wall-stress was calculated with the stopper length and the bottle circumference. The stoppers C and D have been measured in comparison with natural cork of 3 and 5 years old and in comparison with competitor synthetic stoppers X and Y, having both a density of 0.60. The results are shown in Table 5.

Table 5

Stoppers	Force N	Wall Stress, kPa
Natural cork 3 years	247	156
Natural cork 5 years	395	153
Competitor X	230	110
Competitor Y	180	70
Stopper C	410	184
Stopper D	230	112

The curves obtained during the tensile test are shown in figure 1. The results and the graph show that stopper C is closer to the natural cork of 3 or 5 years.

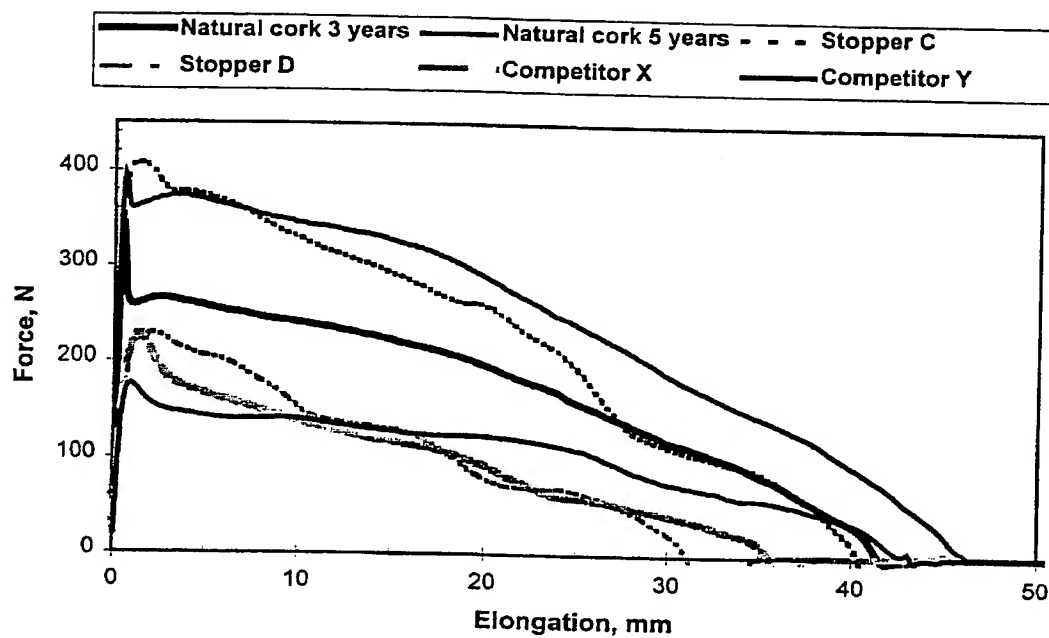


Figure 1